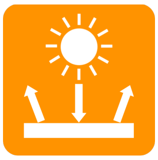
SOLAR INNOVA

looking for the future

PV PANELS REFLECTANCE OF SOLAR INNOVA MODULES

REFLECTANCE OF SOLAR INNOVA PV MODULES



1. Motivation.

A photovoltaic (PV) system does correspond to a large area of glass and metal surface oriented in a single direction. Due to potential dazzle or glare effects, it may therefore seem to constitute a risk when constructed near an airport, a railroad track, or a road, or it could become a nuisance for neighbors when placed near a residential neighborhood.

PV modules, like those manufactured by Solar Innova, indeed reflect part of the energy they receive from the sun, just as any other object or material. However, the PV modules are specifically designed to absorb sunlight instead of reflecting it. This is, for instance, achieved by using glass with a special texturing or even an "anti-reflective" (AR) coating in the cells.

Nevertheless, analyzing the reflectance of PV modules in detail is a meaningful way to quantify the risk of dazzle or glare. Clearly, in this context only the specular component of the visual portion of the reflected light is relevant. The purpose of this technical bulletin is to show that the reflectance of Solar Innova PV modules is low and comparable to that of other common surfaces.

2 About anti-reflective surfaces.

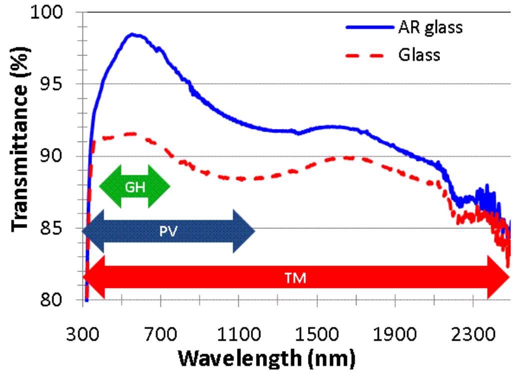
All glass companies that produce low iron glass for solar energy applications strive to optimize process related parameters in the furnace.

A high performance low iron glass exhibits absorptance of less then 1% and a reflectance of 4% on both sides of the glass, resulting in a maximum transmittance value of 91.5% for the best quality glass.

The maximum transmittance is therefore limited to 91.5%. The only way of increasing the transmittance is by reducing the reflectance. This can be done by modifying the surface of the glass, which should have a refractive index of 1.22 after modification.

The AR process is unique since it is a subtractive process that removes material from the glass surface. It uses the glass itself and introduces the anti reflective layer into the glass.

This surface is produced by subjecting the glass to a series of mild chemicals that produces a layer 100 nanometers thick (100 nanometer is 1/10.000 mm) on both sides of the glass. This layer has a refraction index of 1.24 and reduces the reflectance of the glass to 1.5%. The resulting increase in transmittance is 5-6%. The resulting transmittance is 96% to 97% (measured according to ISO 9050 with solar spectrum ISO 9845). AR glass will have a minimum transmittance improvement of 5% compared to unmodified glass, and guarantees the AR surface for 10 years.



Transmittance of glass as a function of wavelength in the range 300 to 2500 nm before and after treatment. The effective wavelength regions for greenhouse (GH), PV module (PV), and thermal collector (TM) applications are illustrated in the graph.

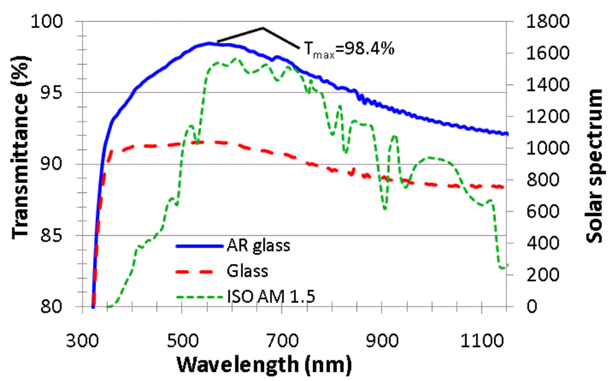
The average transmittance for the three applications; greenhouse, PV module, and thermal collector is:

	T (GH)	T (PV)	T (TM)
AR glass	97,6 %	96,3 %	95,9 %
Glass	91,3 %	90,6 %	90,4 %
Improvement	6,3 %	5,7 %	5,5 %

The AR process is environmentally friendly, since the chemicals are not consumed, and only require minimal replenishment. The production is a closed loop process, where process water is cleaned in the waste treatment system and can be released into nature with no environmental impact. The chemicals used are low in toxicity and used at low concentrations. The production process uses little energy.

3 PV panels.

Our photovoltaic modules is made with silicon cells laminated in solar glass. The PV modules are normally marketed based on their performance rating under Standard Test Conditions (STC). This is done by flashing the modules according to STC norms. For a high quality low iron solar glass 4% of the light is reflected by the front surface and 1% is absorbed by the glass. The glass is laminated to the silicon cells with EVA that has a refractive index of 1.5 which is similar to glass. This means that no light will be reflected by the inner surface of the glass.



Transmittance of glass as a function of the wavelength range 300 to 1150 nm before and after AR treatment for PV applications. A solar spectrum is also illustrated in the same graph. The integrated PV transmittance before and after AR treatment is:

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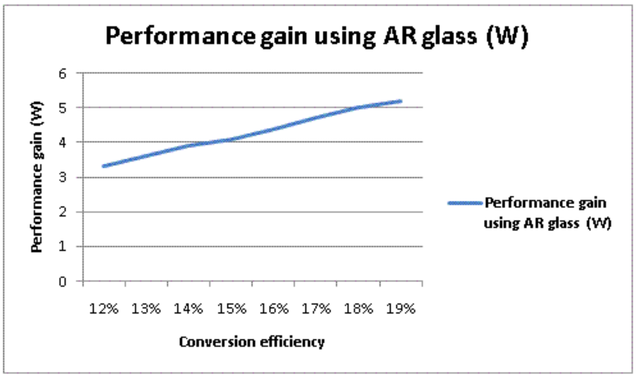
	T (PV)
AR glass	96,3 %
Glass	90,6 %
Improvement	5,7 %

The improvement in the transmittance after AR treatment is 5.7%.
The performance improvement for a PV module where the glass is exchanged with AR glass is: 5.7% / 2 = 2.85%

If AR glass is used the reflectance from the outer surface is reduced by 2.5 to 3.0%. As a consequence of this the transmittance increases by 2.5 to 3.0%. Based on STC conditions that use an irradiance of 1000 W/m², 25 to 30 W more light per m² will reach the cells. Depending on the conversion efficiency of the module the increase in the power is 3.5 to 4.5 peak Watts. The advantages of AR glass depend to a large degree on the conversion efficiency of the PV module. The higher the PV module conversion efficiency the greater the benefit.



The AR treatment of the inner glass surface has the added benefit of improving the bonding between the glass and the EVA. This reduces the risk of delamination during the lifetime of the module.

4. Laboratory measurements.

At an independent laboratory, hemispherical spectral reflectance measurements were performed in accordance with ASTM Standard Test Method E903 with a PerkinElmer Lambda 950 Spectrophotometer utilizing an integrating sphere. Results were obtained for spectral reflection near normal incidence (8°) and as a function of wavelength within the visible range of the solar spectrum.

This was done for the distinct material layer structures typical of Solar Innova PV modules (i.e., aluminum frame, glass over encapsulation and back sheet, glass over encapsulation and silicon surface of the solar cell, and glass over encapsulation and metallization of the solar cell).

5. Calculation of pv modules reflectance values.

Using these laboratory measurements, a weighted average over the area of a given module type and the visible wavelength range of 410 nm to 720 nm of the solar spectrum at air mass 1.5 could be determined:

Module Series	Glass Thickness (mm)	Anti-Reflective Coating	Average Specular Reflectance
SI-ESF-M-M156-60 SI-ESF-M-P156-60	3.2	Yes	2.5 %

SI-ESF-M-M156-72 SI-ESF-M-P156-72	3.2	Yes	2.6 %

Table 1: Average specular reflectance for Solar Innova PV modules with AR coating.

Module Series	Glass Thickness (mm)	Anti-Reflective Coating	Average Specular Reflectance
SI-ESF-M-M156-72 SI-ESF-M-P156-72	4.0	No	4.0 %
SI-ESF-M-M156-60 SI-ESF-M-P156-60	3.2	No	4.6 %
SI-ESF-M-M125-96 SI-ESF-M-M125-72	3.2	No	4.6 %

Table 2: Average specular reflectance for Solar Innova PV modules without AR coating.

6. Summary and conclusion.

Material	Reflectance
Aluminum Roof	74 %
Water	5 %
PV Module without ARC	4.0-4.6 %
Black Asphalt	3 %
PV Module with ARC	2.5-2.6 %

Reflectance measurements from an independent laboratory were used to obtain an average specular reflectance for different types of Solar Innova PV modules. These results are reported in Tables 1 and 2 for modules with and without anti-reflective coating on the front glass, respectively.

To put these results into perspective, Table 3 shows reflectance values for some common surface materials (source: www.landsat.org, www.gsfc.nasa.gov) in comparison to the results obtained for Solar Innova PV modules.

The reflectance of the PV modules is comparable to that of water or black asphalt. It can therefore be concluded, that Solar Innova PV modules are unlikely to constitute an unusually high risk for dazzle or glare.

It is nevertheless important to emphasize that the intensity of light reflected from a PV module surface depends on the amount of sunlight reaching the surface and will therefore vary based on, among others, geographic location, time of year, cloud cover, and PV module orientation. A full analysis to assess the potential impact of reflectance will therefore depend on the specific project site and system design. This is, for instance, detailed in the "Airport Solar Guide" of the U.S. Federal Aviation Association (available at www.faa.gov). The reflectance values provided in this bulletin can be used as input data for such more detailed site specific assessments.